DOCUMENT RESUME

ED 465 749 SP 040 901

AUTHOR Sandoval, William A.; Deneroff, Victoria; Franke, Megan L.
TITLE Teaching, as Learning, as Inquiry: Moving beyond Activity in the Analysis of Teaching Practice.
PUB DATE 2002-04-00
NOTE 16p.; Paper presented at the Annual Meeting of the Educational Research Association (New Orleans, LA, April 1-5, 2002).
PUB TYPE Reports - Descriptive (141) -- Speeches/Meeting Papers (150)
EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Discussion Groups; *Faculty Development; High Schools; *Inquiry; Interpersonal Relationship; Research Methodology; Science Education; *Science Teachers; *Scientific Research; Secondary School Science; Secondary School Teachers; *Teacher Collaboration; Urban Schools
IDENTIFIERS Knowledge Development; Reflective Thinking

ABSTRACT

This paper describes an ongoing high school science teacher professional development project, Beyond Final Form Science, that focuses on developing teachers' ideas of scientific inquiry and inquiry pedagogy. It analyzes the first several months of the project, highlighting analyses of teachers' interactions during monthly professional development workshops. The workshops provided teachers with multiple opportunities to critically analyze students' ideas of science, science concepts, and their own understanding of scientific practice. Data collection involved video recordings of the project meetings. Data analyses illuminated ways in which the professional development activities provided opportunities for teachers to raise important issues around teaching. Results are presented in the areas of locating knowledge in activity, learning what students know, stepping out of the activity, and transitioning toward analysis. Results showed that the teachers' discourse was almost entirely grounded in descriptions of activity or judgement about particular activities. The descriptions or judgements were rarely unpacked or explained. These activity-centered conversations conveyed assumptions about student learning that discounted the role of students' prior knowledge in developing understanding. Activity-centered talk presented an obstacle to professional development and teacher change because it left too much implicit. (Contains 22 references.) (SM)

Reproductions supplied by EDRS are the best that can be made
from the original document.

PERMISSION TO REPRODUCE AND
DISSEMINATE THIS MATERIAL HAS
BEEN GRANTED BY

William A Sandoval

TO THE EDUCATIONAL RESOURCES
INFORMATION CENTER (ERIC)

1

ED 465 749

Teaching, as learning, as inquiry: moving beyond activity in the analysis of teaching practice

William A. Sandoval, Victoria Deneroff, Megan L. Franke
University of California, Los Angeles
{sandoval, vdenerof, mfranke}@ucla.edu

Paper presented at
Session 15.19
"Teacher Identity And Practice In Inquiry Based Science"
Annual Meeting of the American Educational Research Assn., April 1-5, 2002, New Orleans, LA

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION
CENTER (ERIC)

☐ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

SP040701

BEST COPY AVAILABLE

Introduction

Science education reforms call on teachers to adopt inquiry as a central strategy of their teaching (AAAS, 1992; NRC, 1996). Inquiry teaching is rare, and seems to have always been so, despite recurring calls for inquiry teaching over the last fifty years (Tobin, Tippins, & Gallard, 1994; Welch, Klopfer, Aikenhead, & Robinson, 1981). Inquiry-oriented teaching places many demands on teachers. It takes both substantial subject matter knowledge and pedagogical skill to guide students through inquiry, to balance the tension between letting them construct their own path and making sure they learn key scientific ideas (Hammer, 1997). It also takes time, and that demand flies in the face of expectations to cover large amounts of content. Despite these demands, we still want teachers to teach science through inquiry because typical science instruction does not teach most students very much science (NCES, 2001; O'Sullivan, Reese, & Mazzeo, 1997) and even the students who seem to learn scientific concepts have naïve views about how science is really done, and of the nature of scientific theories (see Abd-El-Khalick & Lederman, 2000; Lederman, 1992).

One of the reasons that inquiry teaching may be so demanding, and rare, is that science teachers are unlikely to have conducted inquiry themselves during their own science education. As science education reforms have argued for a shift in instruction, our teachers are largely unprepared. The assumption seems to be that inquiry-oriented pedagogy can be simply adopted. There are several difficulties with this notion. First, teachers' ideas of inquiry-oriented teaching are often quite different from the ideas espoused by reforms (Thompson, Zeuli, & Borman, 1997). There is also a significant literature suggesting that teachers' own ideas of the nature of science are as naïve as their students(Abd-El-Khalick & Lederman, 2000). Teachers and students commonly see science as the accumulated discovery of facts about the world, rather than theories invented and developed by people. They see experiments as a means to directly generate answers to questions, rather than tests of ideas. Considering the education that most teachers have likely had in science, it is no wonder that they hold these ideas. It is also no wonder that they may find it hard to teach inquiry.

This paper describes an ongoing high school science teacher professional development project focused on developing teaches' ideas of scientific inquiry and inquiry pedagogy. We present preliminary analyses of the first several months of this project, focusing on analyses of teachers' interactions during our professional development workshops. These workshops have been intended to provide teachers with multiple opportunities to critically examine students' ideas of science, science concepts, and their own understanding of scientific practice. Through the mid-point of this year-long project, we have found that these opportunities for analysis have raised what we see as important issues of student thinking, learning, and instructional practice. We have also found that the teachers we are working with are struggling to analyze these issues. we show how these struggles are rooted in a discourse abut practice focused on descriptions and judgments of activity. This activity-centered discourse does not take account of student thinking, but takes for granted that students interpret classroom activities in their intended ways. we show how multiple opportunities to analyze student thinking are helping some teachers to acknowledge students' ideas. still, these teachers find it difficult to connect students' thinking to their own practice. Our analysis of teachers' participation in this professional development

project suggests that an important way to change practice is to change teachers' discourse about that practice. Such a change is a significant challenge to professional development.

Beyond final form science

The Beyond Final Form Science project is a yearlong professional development and research project focused on teaching inquiry-based science in urban high schools. Duschl (1990) coined the phrase "final form science" to refer to the way that typical science instruction presents students with currently accepted theories, stripped of the history of their development. Thus, we talk of science concepts as simple factual knowledge, rather than ideas invented by people to explain the world and developed into broad, explanatory theories. The "final form" view of science bears little resemblance to science as it is actually practiced (Latour, 1987). Current reforms define scientific practice as being centered around the notion of inquiry. Inquiry is generally proposed as a process of asking questions, developing conjectures, generating data to test those conjectures, analyzing and interpreting data, and generating conclusions that usually lead to more questions and further conjectures. This process is grounded within a value system, a set of epistemological commitments, for the kinds of knowledge that can be considered scientific. We want to know what practicing teachers understand inquiry to be and what we, as researchers, can do to support teachers' efforts to understand and implement inquiry pedagogy. We are motivated primarily by two issues. First, secondary science education is generally failing in this country, as the overwhelming majority of students leave high school with only the most basic scientific knowledge (NCES, 2001). Countering this trend, inquiry-based approaches to teaching science, especially efforts that use technology to support students' inquiry, have been quite successful (e.g., Linn, Bell, & Hsi, 1998; Scardamalia, Bereiter, & Lamon, 1994; White & Frederiksen, 1998). For such approaches to spread effectively beyond the research projects which have developed them, practicing teachers need to know about them, and need to understand and be able to implement the inquiry pedagogy that underlies such tools.

At the start of the 2001-2 school year, our research team began working with a group of nearly twenty teachers from eight high schools in urban Los Angeles. We recruited our teachers from a group adopting a curriculum for integrated science, called *Science and Sustainability* (S&S, SEPUP, 2000). Integrated science is an approach to organizing science instruction around themes that draw on various science disciplines. S&S uses themes of sustainability to organize science topics. For example, a major thematic unit on "Feeding the world" provides a theme for studying cell structure and function, the components of the earth, chemical elements, photosynthesis, and genetics. S&S explicitly provides opportunities within the curriculum for inquiry-oriented activities. All of the teachers volunteered to join the research project, and most explicitly spoke of a desire to develop their knowledge of inquiry as a way of teaching science. These teachers have an average of fifteen years of experience, and all have been at their current school for at least five years, or the length of their career if less than five years.

Our professional development work with these teachers is primarily organized around monthly workshops during which we explore students' thinking and ways to engage students in inquiry into selected topics. The teachers receive release time to attend. Each meeting is held in the classroom of one of the participating teachers, at a school in a culturally diverse, economically poor part of the city. Each of these monthly meetings is organized around one or two of three

main activities: a) the analysis of student work; b) the analysis of an activity from S&S; or c) collaborative investigation into a science topic targeted by the curriculum. Each of these activities provides an opportunity for what we call here *critical engagement*, teachers' engagement in a thoughtful analysis of an activity or a set of artifacts in a way that can enable them to question their teaching practice in ways that lead to change.

Our focus on student work is inspired in part by the model of Cognitively Guided Instruction (CGI, Carpenter, Fennema, & Franke, 1996), an approach to teacher learning and professional development in mathematics. CGI guides teachers' analysis of students' mathematics problem-solving strategies as a means to break down the idea that there is a single right algorithm for solving math problems, and to show teachers that students are capable of inventing their own effective strategies. We have borrowed from CGI the idea that teachers can usefully analyze student work for what it says about students' thinking. Our goal is to encourage teachers to see the productive aspects of students' scientific ideas, rather than evaluate them solely in terms of their normative correctness. We have asked teachers to bring in samples of student work from the S&S curriculum, and to work together to uncover patterns or themes in the ideas that students express. We have selected topics for these analyses by choosing areas that are covered in S&S and where there is a substantive literature on students' intuitive conceptions. So far, we have analyzed students' thinking about food webs, heat and temperature, modeling of complex systems, and genetics.

Our focus on the analysis of instructional activities is intended to encourage teachers to make explicit the goals underlying specific activities, and to explore how particular activities are likely to help, or not, students learn science. We have chosen activities from the S&S curriculum, and some we have introduced. We have chosen activities that we believe are inquiry-oriented. Teachers' analyses of activities occur through their own engagement with the activity, and subsequent discussion of that. These investigations are briefly introduced, and then we let groups of teachers collaborate on them. following some period of work, usually 40 minutes to an hour, we have a whole-group discussion of the activity.

Our description of these meetings to this point simply provides a sketch of the general form of our professional development work with these teachers. How such activities actually occur and how teachers interact with each other during these activities will become clear in the examples to follow. Besides these monthly meetings, we have asked our teachers to meet once a week at their schools to continue their work on their own. We have regularly observed these meetings in two school sites. We have conducted a limited number of classroom observations of a small subset of teachers in the project. We have also interviewed six of these teachers to learn more about their ideas about inquiry and the challenges of inquiry teaching. Our focus in this paper is on our professional development meetings.

Data sources and analytic methods

Each monthly project meeting is videorecorded in its entirety, and tapes are digitized for subsequent analysis. The focus of recording during any meeting varies with the activities that occur. When the entire group is listening to a presentation, either by the research team or the teachers, we record the entire group. At these times we usually focus on the audience to have a

record of how people are attending to the speaker(s). We train the camera on the speakers periodically and when they are showing some material artifact to the group (e.g., a butcher paper drawing, diagrams drawn on the board, etc.). When the teachers are working in groups, we videotape each group. We use a time sampling technique in an effort to get detailed data about teachers' conversations from as many teachers as possible, by filming each group for approximately five minutes at a time. Groups are usually formed by proximity, the teachers sitting near each other would form a group. Only rarely do we assign people to specific groups, because we think a particular individual can facilitate group work or because we want to maximize interaction among teachers from different schools. The data for this paper come from meetings held September, 2001 through January, 2002.

We have used techniques of interaction analysis (Erickson, 1992; Jordan & Henderson, 1995) to explore how the teachers participate in professional development activities. Each videotape has been logged into segments identified by changes in participation structure, such as changes from whole group discussions to small group breakouts. We have viewed the entire corpus to identify important and interesting events. These events have been transcribed and analyzed for characteristic features. As new features of events have been identified, tapes are reviewed for further evidence of those features. These analyses are ongoing, and we have not yet formed a fix set of coding categories. We have identified, however, a recurring pattern of activity-centered discourse in teachers' interactions.

An activity-centered discourse of teaching practice

Our analyses illuminate ways in which our professional development activities have provided opportunities for teachers to raise important issues around teaching. We have also noticed ways in which teachers either cut off these opportunities or do not take advantage of them to a full extent. We present several examples here to show how teachers participate in these activities. These examples have been chosen because they represent various ways in which issues that seem, to us, ripe for analysis get raised through our professional development activities, but are not pursued. To us, the most striking feature of teachers' discourse is that it is almost entirely grounded in descriptions of activity or judgments about particular activities. These descriptions or judgments are rarely unpacked or explained. These activity-centered conversations also convey assumptions about student learning that discount the role that students' prior knowledge can play in developing understanding.

The examples we present are mostly verbatim transcripts of conversations, but occasionally include descriptive summaries of parts of the event to shorten examples for presentation. Comments are denoted by square brackets. Ellipses denote dialog that has been trimmed to shorten the example, but they do not change the meaning of speakers' utterances. We have used commas in transcripts to indicate short pauses in speech. Double slashes (//) indicate the speaker being interrupted. The date of the meeting at which the conversation took place is noted at the end of each example. All of the teachers' names presented here are psuedonyms.

Locating knowledge in activity

In our meetings, teachers' analyses of students' thinking or their analyses of the value or effectiveness of instructional activities are grounded almost entirely in activity. It seems to be

taken for granted that students will learn what they are intended to learn from their participation in an activity. In this first example, the whole group has just watched a video clip of a model teacher interacting with groups of students in a high school physics class, as they work in pairs to deduce relationships in optics. After the video we ask the teachers to write down three things that strike them about what they saw in the video. After about five minutes, we ask the teachers to form groups to share their responses. Greg, Kathy, Frank, and Cindy sit in desks facing each other. They have been sharing their responses when Kathy raises a question about assessment.

> *Kathy: I think at the end, I would be curious, to see some kind of, more of an explanation, rather than just [can't hear]. You know, some kind of an assessment.*
> *Greg: They weren't supposed to understand it.*
> *Kathy: They weren't?*
> *Greg: No, because later they're going to learn how lenses work. They're learning pretty important stuff. If the object is far, then the image will be closer, and so on. The next thing they're going to do is...[can't hear]. [10 second pause] I put you have to know what his long-term goal is. It's like I said before, he doesn't need to ask, what do you think is gonna happen, because, it's just an experience that is going to be repeated in several other, situations [can't hear]. He's getting what he wants. Everybody holds the lens here, everybody moves it, everybody makes an image. That's all he really wants to do. Because later you have probably something to hold it so it doesn't move around, and you have the paper, something so it, make better measurements, and so forth.*
> *Kathy, Cindy, and Frank have been watching Greg as he describes what will happen next. As he finishes, all three look down at their desks and there is a long pause. Then Frank starts to share his observations. [Oct. 1, 2001]*

This exchange occurred during our second project meeting of the year. We showed a video clip of a physics lesson on optics as one model for how to structure inquiry, and we asked each teacher to write down three things they noticed or took from the clip and then discuss them with each other. Here, Kathy raises an issue that concerned her, the appropriate way to assess if students are learning what they should from the activity. Greg's response challenges the need for assessment, by claiming that understanding how lenses work was not a part of that particular activity. The purpose of that activity was to provide students with a shared experience of optical phenomena to set up subsequent investigation of how lenses work. Although Greg had not seen this particular video before this day, he anticipates exactly what will happen next (which suggests that this is a common sort of lesson in physics, Greg's subject area). His argument seems to be that subsequent activities will lead students to the understanding that Kathy seeks through her question for assessment. The conversation is not about what such an explanation would say, and it is also not clear from the Greg's description how further activity will lead to students' being able to provide an explanation for how lenses work. He describes what he thinks students would do next, and appears to take it for granted that they will learn what they are supposed to learn from subsequent activities. Greg may not actually think this, but he has left his justifications for his position implicit. This seems to inhibit the others from pursuing this, perhaps because he is a physics teacher and they defer to his expertise. Nobody picks up on the fact that he has not dealt directly with Kathy's request for a deeper assessment, although this provides a rich opportunity to consider how students' work with lenses could be structured to promote a deep understanding, and the teacher's role in that structuring.

Learning what students know

Several of our sessions have involved analyses of student work. Our goal for such analyses is to guide teachers to see both that their students have ideas when they come into the classroom and that these ideas are rational and even effective in everyday reasoning contexts. They are not simply wrong. Another aspect of this focus on student thinking is that we would like the teachers to be able to interpret students' performance on instructional activities from the students' perspective. Doing so would provide the teachers with useful insights about how to better structure activities. Focusing only on how students' answers are wrong does not provide leverage to help them build on what they know.

> *About six teachers and a researcher are sitting in a group discussing an S&S activity to draw and analyze a food web of a freshwater stream. Susan begins to explain how she had done this as a whole class discussion and drawing, on the board, because her previous experience had been that students' food webs came out "all skewed." James interrupts to note that he did not do it that way, and that his students did not construct accurate food webs. The researcher asks James what he learned about student thinking from that.*
> *James: the decomposers, the bacteria, we talked about what they were and we agreed upon it, and [pause] 70%, most of the kids, put the bacteria in the center of the food web.*
> *Vickie: Ok. Why did, why did they do that?*
> *James: [can't hear]*
> *Vickie: Right.*
> *James: [can't hear] it made it, it made it really, really clear that we need to have a decomposer, and the decomposer decomposes, everything. They had the plankton feeding into the bacteria, which fed [pause, looking at students' food web]*
> *Susan: See, and when I went over it on the board//*
> *James: Right//*
> *Susan: I said what's bacteria gonna be? And it came back, decomposer. So, let's set them off to the side for a minute, and we set them off to the side. I said, now let's work from [unintelligible; turns from James to Vickie]. And so now that they had it off to the side [turning back to James] and they worked it, I said now, where does bacteria fit in? and they said, everything. And so I said, well, where should I draw the arrow? [turning back to Vickie] and so they came up with it, but, I was talking them through it.*
> *James: Yeah, I thought that, I'd guided them the same. Said, look at the book, look at the picture in the book, because it shows the decomposers over here. We need to have a decomposer just like in the book. You know, we talked about this. But [pause] not too many of them put it as a decomposer. [Nov. 5, 2001]*

James responds to Susan's description of the food web construction in her class as an opportunity to raise a problem in his class: the problem that students, constructing their own food webs, usually failed to place bacteria in the right place on the food web. Both Susan and James share the same goal for the activity, the construction of an accurate food web. Vickie, the second author, prompts James to consider what students' performance says about what students understand. James recognizes that students saw the importance of having a decomposer in the

web, but is concerned that they have drawn the food web incorrectly. For both Susan and James, a correctly drawn food web signifies conceptual understanding. They seem to see the success of the activity in terms of the accuracy of the constructed artifact. Susan appears to have some sense that an accurate food web is hard to construct, so she avoids the difficulty by constructing the web herself with student input. For his part, James seems surprised at the difficulty students had. They had talked about it, and looked at the book, and still most put decomposers in the wrong place.

There are two things we want to point out about this conversation. First, neither James nor Susan seem to view students' ideas as something to work from. Instead, both see normative accuracy as the measure of success. Susan avoids any straying from the normative food web by drawing the web herself and guiding students' input into its construction. It remains unclear, despite Susan's confident assertion that students came up with the ideas, what most of her students understood from the activity. James sees his students' performance primarily in terms of its deviation from normative accuracy, rather than as an opportunity to publicly recognize the insight suggested by placing decomposers at the center of the web, and to then point out the difficulties in that placement. Second, none of the other four teachers listening to this dialogue became involved in the discussion, nor did anyone push for further explanation from either James or Susan, besides the researcher. It could be that some of them had not gotten to this particular activity yet, and so they felt they could not provide any insight.

Stepping out of activity

On the rare occasions when a teacher steps out of activity, to attempt to characterize the nature of an activity rather than describe what happens, their efforts at analysis are rarely taken up. We have seen only a few instances of this sort off analysis. The following is taken from the video clip analysis presented earlier, where teachers are sharing their responses to the video.

> *Henry, April, Grant, and Samantha form a group, sitting in desks arranged in a circle. Samantha first reports her impressions, difficult to hear on our tape.*
> *Grant: [joking] I noticed none of them were trying to light anything on fire.*
> *All four laugh.*
> *Henry: Well, I kind of looked at it a different way. I was thinking about the lesson itself rather than what was happening in the lesson... It seemed like it was a lesson on well-known principles of physics, that, in other words I was thinking that the teacher knew the answer but the students didn't. That's not the kind of inquiry where you go inquire, let's inquire together and see what happens, but it was [pauses, with sort of a frown, holding hands in air. Pushes both arms forward and down for emphasis] here, you know, there are some well known principles of physics that are going to be demonstrated here, let's have students figure out what they are. [pauses, looks down at paper] So, the teacher knows what's going to happen... So, the teacher is in a position of authority.... Rather than we're all down here together... so, this is a particular kind of inquiry, which probably gets practiced more often.*
> *While he has been speaking the other three have all been looking down, thoughtfully, at their own papers. As he finishes, April, Samantha, and Grant all look up at Henry. After a several second pause, Henry, looking at Samantha next to him, gestures toward the front of the room and says, "Is that what they wanted?*

I don't know if that's what they wanted, but that's just what I took out of it." Henry then turns to April, and she begins to report what she noticed. [Oct. 1, 2001]

From our view, Henry's monologue provided an excellent opportunity for the group to discuss the kind of inquiry being modeled in the video. Henry has raised an issue about guidance, about the role the teacher plays in framing an inquiry for students and what that means for the students. Indeed, Henry has noticed an important feature about the example that the teachers have viewed. The other teachers in his group, however, fail to take up this line. Why? One reason may have been that Henry's initial comment about seeing things another way may have been received by the other teachers' as a critique of their own reports, that they had focused on the wrong thing. Their reaction also suggests, though, that the other teachers in this group did not know how to respond to his comment, what to make of it. Henry's analysis of the video example was in terms of the kind of inquiry it represented, whereas Samantha's and Grant's reports were in terms of specific activities they saw students engage in. These are quite different levels of analysis. They are not unrelated, though. Our goal for these activities is that teachers would work to relate their various observations or to notice their differences. Most often, as here, they let such opportunities pass.

Transitioning toward analysis

The kind of analysis that Henry attempted to engage his colleagues in during our second session remains uncommon and apparently difficult for most of these teachers. Yet, some of the teachers are beginning to see that the group can help them analyze student thinking and how that analytic effort can be used to inform their instruction. They are becoming more cognizant of student thinking, but remain unsure about how to respond to it.

Samantha, Grant, and Susan ask the whole group, at the beginning of a meeting, to help them with a problem they have discovered. Their students do not understand energy transformation, even after they have completed several lessons about it. Specifically, a culminating activity about energy flow is for students to generate five examples of energy transformation. Students did not do what the teachers expected.
Samantha: And so they were so supposed to explain where the energy went. And so you had the fire heating the bottom of the pan, you have from the flame heat going into the bottom of the pan but you also have heat going into the air.
Bill: Ok
Samantha: So then the stuff, the pan gets hot and then that heats the water in the bottom... and so the water at the bottom heats the water above it... and so you're supposed to draw arrows to show where everything goes...
Bill: Ok. And, what did kids draw?
Susan and Samantha laugh.
Samantha: They drew a pot. And a flame.
Grant: They drew a pot on a stove, where an energy diagram is just arrows and words. But//
Bill: Alright.//
Susan: They couldn't understand it, because they couldn't interpret when we asked for examples, they just drew a blank.
Grant: Right. Instead of actually drawing an energy flow diagram, not

necessarily a picture...
Susan: Right. And understanding how energy transforms, they couldn't understand that, they couldn't grasp that as well. [Jan. 14, 2002]

Here, as in earlier examples, the conversation is centered in activity, in the intended and actual outcomes. What is different about this episode is that the teachers brought this to the group themselves. That is, they asked all of us to help them analyze why students did not yet understand energy. At the end of this bit of the conversation, Susan is frustrated that students could not grasp what they had been asked to do. We followed up at this point by asking the teachers to tell us more about what they did. Samantha mentioned that they (individually, in their own classes) asked students questions about what they know, and did "simple demos." When asked, Samantha said the questions they asked included what students thought energy was. This led to a conversation involving most of the teachers about what students think energy is. Students' ideas about energy, to no surprise to us or the teachers, were grounded in everyday uses of the word: energy is needed to run cars, people eat food to get energy, there was an energy crisis in California last summer. The teachers seemed to hold conflicting views about students ideas during this conversation. On the one hand, they recognized that students had ideas about energy, but seemed surprised that they did not have a fuller understanding. Susan mentioned that she thought it was funny that students said that a moving car had energy. Samantha said that her students could give examples of energy, but did not know where it comes from. Grant said that students found it hard to see energy "as something that happens," referring to the shift from potential to kinetic energy.

Throughout this conversation Samantha, Grant, and Susan gave many examples of students' thinking, but they seemed genuinely perplexed at the source of students' ideas and about how to respond to them. They were disappointed that the activities in the S&S curriculum, at least as they had enacted them with their students, did not seem to improve students' understanding. We suggest that part of this perplexity is rooted in an idea that doing activities is sufficient to lead to the intended conceptual understanding, regardless of students' ideas to begin with. There is also a sense that the solution to a problem found in one activity is to try another one. As the conversation continued, we pushed the teachers to recall examples of what students actually said during their class discussions about energy and whether or not those made sense.

Samantha: Mine said that sunlight was energy.
Bill: Is that a sensible idea? Does that make any sense?
[discussion of solar energy and other sources of the idea of sunlight as energy]
Samantha: So that, that makes sense to them.
Bill: Does it make sense to you guys, as scientists or science teachers, to say that the sun is energy? Is, does that make sense [pause] from an expert kind of way?
Howard: I did a little lecture on that. that the energy from the sun is electromagnetic energy, absorbed by the ground, converted to heat energy, the heat energy warms the atmosphere, and that's why, that's where we get our heat from. [Jan. 14, 2002]

Ultimately, the answer offered for whether or not students' ideas make sense is to describe a lecture about the normative view. Again, students' thinking is not directly addressed. Instead, an alternative for communicating the correct view is offered - just give the right lecture. The

conversation continued for several minutes after this, returning to possible activities or ways to tell students about energy without getting to how students' ideas influence their participation in activities. We spent the first fifteen minutes of this particular meeting discussing this issue. What we see here are teachers that are genuinely trying to understand what students are thinking, and looking for help in understanding why the activities that they thought would develop normative conceptions of energy and energy transformation did not seem effective. What they are not yet able to do is analyze the details of activity in terms of students' prior ideas and why the activities do not seem to change these ideas. Again, we think this indicates that the teachers believe that the completion of certain activities will unproblematically lead to learning, and they are perplexed and frustrated when it does not.

Discussion

We are working with teachers who want to improve their teaching, who believe that inquiry is an important approach to science learning and teaching. That is why they volunteered to work with us. To be sure, their ideas about what that means are not identical, and the level of interest and commitment to inquiry teaching varies. As a group, though, their interest in learning about inquiry and using it with their students is high. Over the first six months of this project we have engaged these teachers in a variety of activities intended to help them analyze students' thinking and curricular activities, as a way into examining their own practice. Although our analyses are preliminary, we have seen some important ways in which such analysis is constrained. We think the main reasons these constraints arise are centered in the teachers' discursive practices in these meetings. Their talk about teaching is grounded in descriptions of activity, and these descriptions are rarely challenged or pressed. In coming to understand these patterns of talk and interaction, we are striving to understand how professional development can change them.

As the examples we have presented suggest, these teachers' talk about teaching and learning is grounded in activity. Most of our teachers, most of the time, ground talk about their practice and about student learning in descriptions of activities that their students have done. Hammer (1999) noticed this difference in talking between himself and teachers in terms of diagnoses of students' learning. He noticed that he analyzed student learning in terms of conceptual models, whereas teachers analyzed student learning in terms of what activities could be used to correct a misconception or, retrospectively, how an activity should have been done differently to avoid a problem. We have noticed thi same difference, and it seems to occur in many contexts. We, like Hammer, do not want to say that this activity-centered discourse is wrong. It can be diagnostic to the extent that it can uncover, as was the case with James, whether or not students do an activity in the intended way. A major role of activity-centered talk, as exemplified here separately by Greg and Susan, is that it is prescriptive, or prognostic. Greg's counter to Kathy's question of assessment is that later activities will step students through desired reasoning. Susan's response to James's dilemma is that a different form of activity will avoid the problem.

Activity-centered talk presents an obstacle to professional development and teacher change because it leaves too much implicit. It takes for granted what students learn from engaging in particular activities, as suggested by Greg, without trying to characterize student learning within any conceptual framework. It leaves unsaid the reasoning behind curricular decisions, or the effects of such decisions. It assumes, as in the exchange between Susan and James, the benefits

of one form of an activity over another. From her description, none of the listeners to Susan's description of her food web lesson could decide if her students understand food webs any better than before.

We want to privilege a more explicitly analytic discourse, because such a discourse would uncover assumptions about student learning, effective teaching, and the nature of science. An analytic discourse would elicit justifications for particular instructional activities and pedagogy, justifications made in terms of some specific set of goals for student learning.'An analytic discourse would seek causes for the success or failure of a particular activity, and would, in fact, re-frame the criteria for success. To return again to the James and Susan exchange, since there the issue of students' understanding was explicitly raised, Susan's activity could have been analyzed in terms of James's outcome. That is, the group could have asked whether or not they could say for certain that Susan's students understood food webs. They could ask what they would need in order to find out. They could usefully ask themselves why students in James's class did not find the food webs in the book and the class discussion to be self-evident, and so on.

How can a more explicitly analytic discourse be encouraged and supported? We have seen that by engaging teachers in opportunities to analyze aspects of their work, substantive issues are raised. It seems, though, that these teachers need more support for moving beyond their activity-centered discourse. It is likely that such supports have to be both cognitive and social. Cognitively, the teachers may not know how to productively engage in the kind of analysis we want them to. In that case, simply providing opportunities for analysis is not enough. We need to develop strategies to guide teachers through such an analysis. One strategy is that we, as the professional developers, could more explicitly model the kind of analysis we want them to engage in. We saw above two examples of us trying to model a more analytic discourse, by pushing the teachers to think about what their students know. These examples suggest that such attempts need to be pursued more, to be sustained. We also could probe the teachers to make explicit what they leave implicit. For example, had one of us been participating with Greg and his colleagues, we could have asked why the sequence of activities would lead to students' learning and how we would know.

Socially, we have to recognize that such analysis is professionally and personally risky. We believe that part of the reason that teachers have not pushed each other to explain themselves more fully is that they do not want to open themselves to the criticism. They already work in an embattled position. Fifty percent failure rates are common in science classes in Los Angeles. Principals, parents, administrators, and politicians all place the responsibility for student learning, and blame for the lack of it, on teachers. Many of the teachers we are working with are already extending themselves simply by trying to understand inquiry-oriented pedagogy, and are out of step with other colleagues at their schools. Criticism of particular activities could be interpreted as attacks on one's competence. Amplifying that concern is that teaching integrated science means that all of these teachers are teaching out of their own subject expertise at least some of the time. In our meetings, this carries a risk of exposing one's lack of knowledge about science. One of the teachers recently confided to us that she felt intimidated by these possibilities and that this made her think twice about contributing to the conversation.

Certainly, the kind of critical analysis we hope to promote is not typically viewed as part of the teaching culture. Teaching has been characterized as an artisan culture (Huberman, 1993), where each teacher is free to craft their practice in the way that they see fit. Such personal judgment, in fact, must be central to any notion of teacher professionalism and teacher inquiry. Personal judgments of best teaching practice, however, ought to be tied to critical standards about what best practices are and what the bases of such practices are. Such critical standards are communal. Science provides a useful analogy here. Scientists work within disciplinary communities of practice, and these communities share ideas about what questions are important to answer, what good answers look like, and what methods are acceptable for generating good answers (e.g., Kuhn, 1970). Questions, theories, and methods change over time, but the need to square individual efforts with communal standards of acceptable scientific practice remains. The work we are engaged in with these teachers is thus an effort to articulate what such standards for science teaching, and specifically inquiry science teaching, might be. We are attempting to build a community of teachers that can be honestly critical of their own teaching practice, and can analyze the relations between what they want students to learn, how students think about the natural world and about science as a human enterprise, and instructional activities.

Change is hard, and it takes time. We have really just begun our work with these teachers, and our analyses here suggest a set of issues that we must attend to, and we think others may need to attend to as well. The primary issue we see is the need to shift teachers' discourse away from a focus on descriptions of or implications about activity, to an explicit analysis of the justifications behind particular activities and the evidence available for understanding them. As our work unfolds, we expect to learn more about teachers' views of themselves as teachers, as learners, and as practitioners of science, and how these views influence their interactions with their colleagues and their teaching. We have deliberately focused on teachers' participation in professional development meetings because we believe their forms of participation here suggest why it is that professional development seems to have such little impact. The shift to a thorough, open analysis of their own teaching practice carries learning demands and social risks that have perhaps been underestimated. We are cognizant that we have left out an important part of this picture, namely these teachers' classroom practice. Ongoing work includes frequent classroom observations and an effort to connect teachers' actual practices with their talk about such practice in these settings. Yet, as we gather more data about these teachers, the central issue remains that their own talk about that practice needs to become more explicitly analytic, more directly centered on comparing what they want to do, what they think they do, and what they actually do. We are, therefore, less interested in showing that our professional development program works, in terms of changes to teachers' actual practice. We want that to happen, but more than that we want these teachers to come to a better understanding of their own practice and how they can change it. We also want to understand how we, as researchers, can support that process over time. For that, it seems more important to look closely at what is happening during professional development rather than at its effects.

Acknowledgements

This work is supported by the Arthur Vining Davis Foundations, although the views expressed here are our own and do not necessarily represent the views of the Foundations. We are grateful to Irene Swanson and her staff at the UCLA Science Project for their support, and to Charles

Framularo for research assistance. We especially want to acknowledge the teachers participating in this project for all of the work they have done, and for all they have taught us about themselves and their struggles to teach science in urban schools.

References

AAAS. (1992). *Science for All Americans*: AAAS.

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: a critical review of the literature. *International Journal of Science Education, 22*(7), 665-701.

Carpenter, T. P., Fennema, E., & Franke, M. L. (1996). Cognitively Guided Instruction: A knowledge base for reform in primary mathematics instruction. *Elementary School Journal, 97*(1), 1-20.

Duschl, R. A. (1990). *Restructuring science education: the importance of theories and their development*. New York: Teachers College Press.

Erickson, F. (1992). Ethnographic microanalysis of interaction. In M. D. LeCompte & W. L. Millroy & J. Preissle (Eds.), *The handbook of qualitative research in education* (pp. 201-225): Academic Press.

Hammer, D. (1997). Discovery learning and discovery teaching. *Cognition and Instruction, 15*(4), 485-529.

Hammer, D. (1999). *Teacher inquiry*. Newton, MA: Center for the Development of Teaching, Education Development Center, Inc.

Huberman, M. (1993). The model of the independent artisan in teachers' professional relations. In J. W. Little & M. W. McLaughlin (Eds.), *Teachers' work: individuals, colleagues, and contexts.* (pp. 77-103). New York: Teachers College Press.

Jordan, B., & Henderson, A. (1995). Interaction analysis: foundations and practice. *Journal of the Learning Sciences, 4*(1), 39-103.

Kuhn, T. S. (1970). *The structure of scientific revolutions* (2nd ed.): University of Chicago Press.

Latour, B. (1987). *Science in action*. Cambridge, MA: Harvard University Press.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: a review of the research. *Journal of Research in Science Teaching, 29*(4), 331-359.

Linn, M. C., Bell, P., & Hsi, S. (1998). Using the internet to enhance student understanding of science: The knowledge integration environment. *Interactive Learning Environments, 6*(1-2), 4-38.

NCES. (2001). *Science: the nation's report card 2000.* Washington, DC: National Center for Education Statistics.

NRC. (1996). *National Science Education Standards*. Washington, DC: National Academy Press.

O'Sullivan, C. Y., Reese, C. M., & Mazzeo, J. (1997). *NAEP 1996 science report card for the nation and states*. Washington, DC: National Center for Education Statistics.

Scardamalia, M., Bereiter, C., & Lamon, M. (1994). The CSILE project: Trying to bring the classroom into World 3. In K. McGilly (Ed.), *Classroom lessons: Integrating cognitive theory and classroom practice* (pp. 201-228). Cambridge, MA: MIT Press.

SEPUP. (2000). *Science and sustainability*. Berkeley, CA: Lawrence Hall of Science.

Thompson, C. L., Zeuli, J. S., & Borman, J. (1997). The science reforms: Mapping the progress of reform and multiple contexts of influence, *Paper presented at the Annual Meeting of the American Educational Research Assn.* Chicago, IL.

Tobin, K., Tippins, D. J., & Gallard, A. J. (1994). Research on instructional strategies for teaching science. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 45-93): Macmillan.

Welch, W. W., Klopfer, L. E., Aikenhead, G. S., & Robinson, J. T. (1981). The role of inquiry in science education: analysis and recommendations. *Science Education, 65*(1), 33-50.

White, B. Y., & Frederiksen, J. R. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition & Instruction, 16*(1), 3-118.